# Operational Challenges at LIGO

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# Questions

- What are the challenges in the Operation and Maintenance of a facility?
  - » Meeting user needs with limited resources.
  - » addressing short and long term maintenance.
  - » quality assurance.
- What are the essential elements for successful outcomes from a large facility?
- What are the barriers?
- Suggested areas for improvement

# Remote, rural observatories

- Technical need for large, flat spaces and quiet neighbors, as well as continent-scale distance between the LIGO observatories.
- This created the need for providing facilities services appropriate for cutting-edge, large-scale, operations without proximity to the mother campuses.
- LIGO's facilities and scientific instrument are inseparable, so both science and engineering staff are ideally located at the observatory sites.
- The LIGO detector must run 7x24 during runs (since Nature can send events at any time), so a specially-trained corps of operators is in place at each site.

# Observatory sites

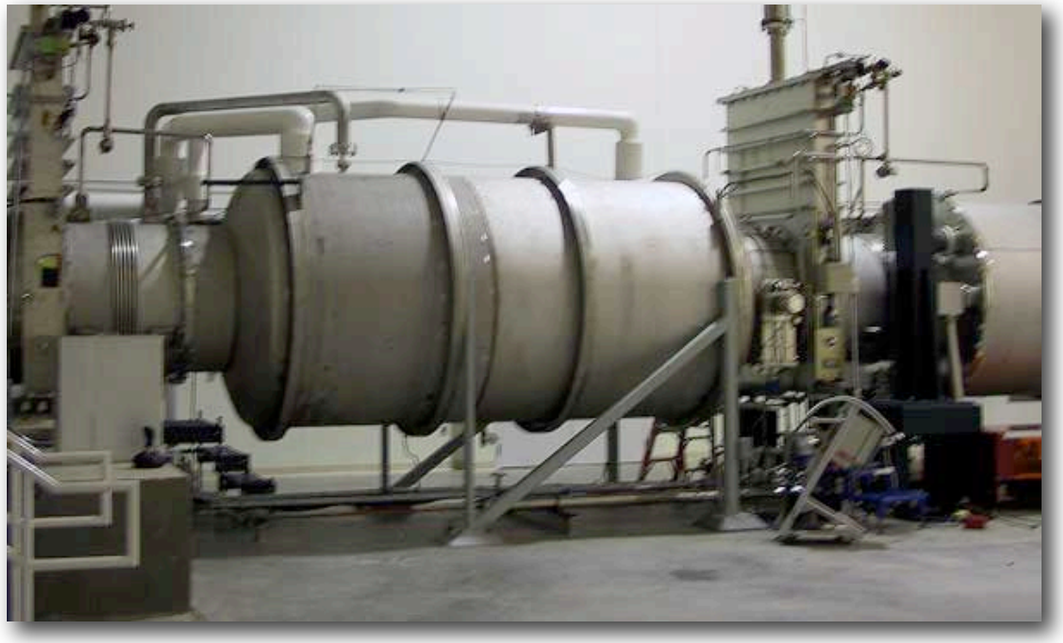
LIGO

# "Small town" hosting high-tech in remote site

- LHO: 1500 acres, LLO: 180 acres.  Erosion control, flood control, grass and tumbleweed mowing/abatement.  (by comparison, Caltech's Pasadena campus covers 125 acres.)
- Access control and security.  (Livingston site has 16 km of border, with forestry, hunters, etc. on other side of fence.)
- 13+ miles of paved access roads.
- Potable water supplies, sewerage, treatment, testing and permitting.
- Fire water storage, distribution, pumps, hydrants, sprinklers all maintained to code.  Fire control systems within buildings, including some gas systems for critical electronics and computers.
- 13.6 kV 3-phase power distribution to 480 V 3-phase panels, special balanced 117 V technical power for detector electronics, requiring expertise in the interesting parts of the NEC.
- Highbay and clean lab areas, with HEPA-filtered air and cleanliness protocols, precise temperature and humidity control, special low-vibration HVAC fans, remote chillers and plenum space to reduce. temperature gradients.  Bridge crane coverage, fork trucks, man lifts, etc.
- Office space, auditoriums for collaboration and outreach meetings, conference rooms.
- Need to maintain facilities in way that anticipates 20+ more years of operation.

# Vacuum Equipment

- Example of extemely valuable equipment/facility that needs extra protection: failure could cause **years** and millions of dollars to repair.
- 16 km of 1.2 m diameter SS tubing, with numerous chambers for detector components.
  - » Total volume 20 million liters.
  - » automatic control.
  - » exact alignment set by GPS, will require periodic recheck.
  - » inspection required every two years.

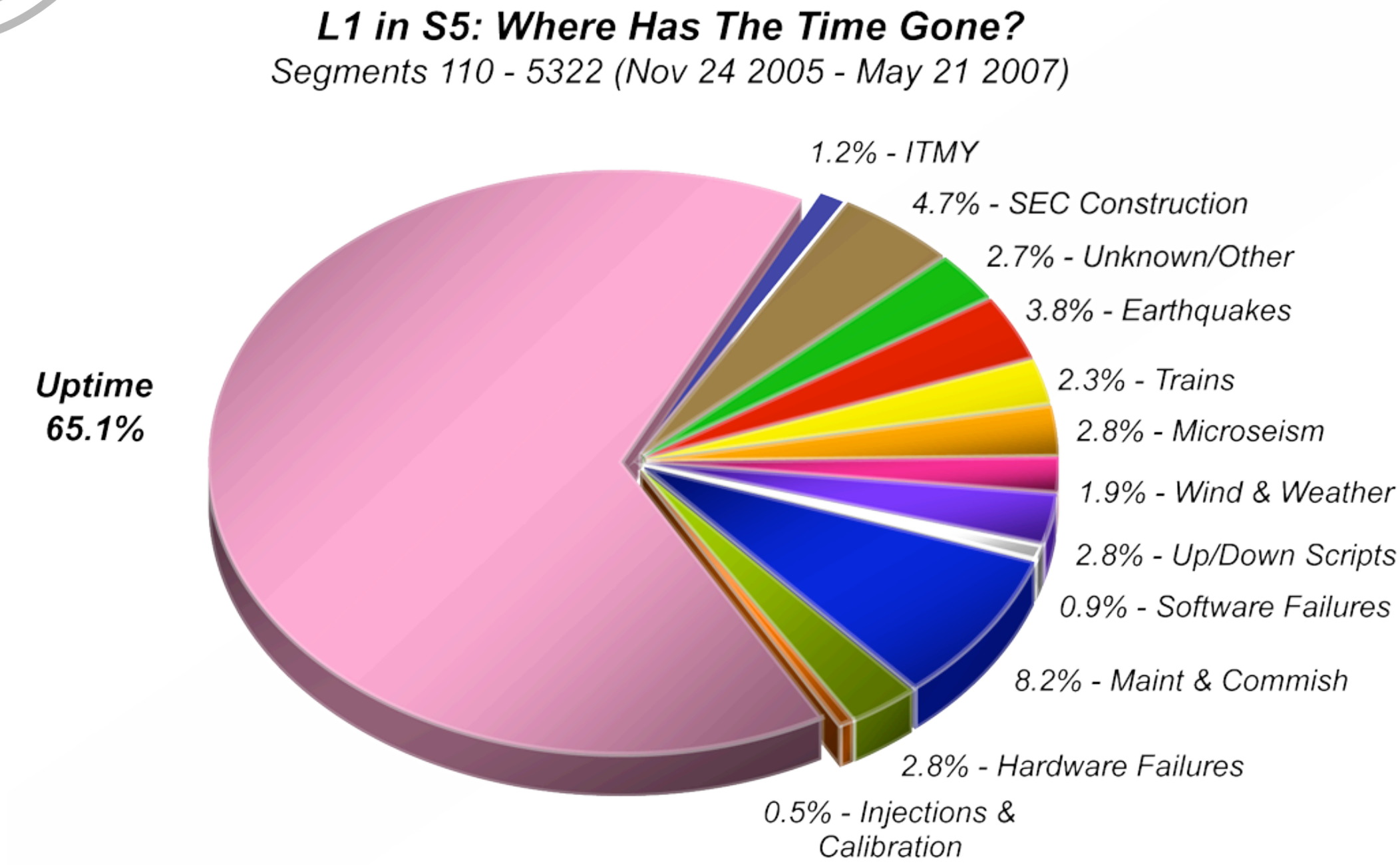


- Hundreds of pumps of eight different types.
  - » Large LN2 cryopumps, with outside silo tanks, refilled weekly, regenerated every few years.
  - » RGA and gauges, telemetry to control room data system.
- 16 km beam tube enclosure.
  - » Thousands of caulk joints between concrete sections and against road, which require periodic inspection and repair.  Major renovation every decade.

# Modes of operation

- Multiple missions:
  - » Operation of Initial LIGO detector, plus incremental improvements.
  - » Site and Vacuum equipment maintenance.
  - » Research, development and construction of Advanced LIGO detector components.
  - » Education and public outreach (e.g., LIGO Science Education Center at Livingston. Staff are often greatly outnumbered by children or teachers!
- Phases of operation:
  - » 7/24 data collection during science runs
    - – Staff assignments are adjusted, and family life altered to operate detector as reliably as possible.
    - – Creative technological change, academic approach towards experimentation with hardware and software ‘improvements’ severely curtailed.
    - – site activities adjusted for minimum disturbance (vibration and E/M interference). Contractors trained to do maintenance during 4 hour/week period.
  - » Detector Installation & Commissioning
    - – Staff augmented with traveling teams expert in various subsystems (engineers, operators and physicists), as well as overall commissioning experts (largely physicists.) This can create town versus gown conflicts, even among Ph.D.’s.
    - – Students, postdocs up every night to advance detector understanding and to make improvements.

# Time during science run




- Continuing challenge in LIGO observatory operations is to squeeze the multitude of thin slices in the pie chart.

# Safety, documentation, and all that…

- The LIGO detector is much more complicated than the experiments most of us experienced in grad school.
  - » tens of thousands of ‘signal’ pathways (analog, digital, computational, RF, hydraulic, pneumatic, etc.) must be working to spec in order to maintain low-noise sensitivity to gravitational waves.
  - » minor ‘improvements’ to these things that are not accompanied by documentation and training are not generally helpful.
  - » so, those of us who did not get training in a similar operation need to adjust our attitudes towards what seems to be absurdly bureaucratic.
- Our safety goal is no injuries.
  - » attitudes based on academic autonomy have to be gently but firmly adjusted.
    - – example: in my graduate school (unnamed institute of technology in New England), half of my classmates had minor injuries or took minor laser beams in the eye.
    - – example: “When the red light is on above the door, I can do anything I want inside, just like we did it at <unnamed ivy league school in New Jersey>.”
  - » staff and visitor safety training has to be complete and documented.
- Question: what is the best way to introduce new people to these issues?

LIGO

# Academic attitudes

- Scholarly tolerance and appreciation of a variety of ideas, attitudes, paradigms.
  - » We can't and shouldn't live without it! Creative freedom led to all of the science and technology we enjoy and rely on.
- Academic approach of developing people
  - » weeding out leading to failure and attrition, as in school. This can lead to hazing as a tool to forcible weed out those who don't fit in. Professional approach is to help team members rather than force them out.
- Active and passive subversion of group's goals, policies and choices.
  - » Infighting long after various decisions are made.
  - » Multiple teams working on same thing, even when a mission is under staffed.
  - » N.I.H. syndrome.
- Subversion can be good and bad.
  - » Good: Alternative designs and methods ready if needed.
  - » Bad: Dilution of effort, lack of respect for colleagues working on baseline.
- QUESTIONS:
  - » When and how do we draw the line? What are some examples of times when we erred?

# Regional cultural issues

- A Large facility, almost by definition, must engage its local surroundings and culture.
  - » It is not too surprising that the people at LIGO's founding institutions (Caltech & MIT) have somewhat different cultural attitudes than a staff that works effectively in south Louisiana.
- Although most of our institutions seek out and value diversity, sometimes a choice needs to be made between alternative points of view:
  - » Burn wood and paper rubbish in open fire, or pay to haul it away?
  - » Site holiday for Mardi Gras or for Presidents' Day?
  - » Serve international visiting scientists crawfish? Strong-arm local caterers to provide vegetarian meals?
  - » Do we recycle office waste? Have the Boy Scouts to take used cans?

# Crisis Management

- With apologies to Tip O'Neil, "All crises are local."
  - » Home institution's resources may be too far away to help in most cases. They expect continual **communication**, and they tend to relay questions, concerns and a string of suggestions during a crisis. lesson learned: the person in (at least temporary) charge of the response is ideally based locally.
- Environmental:
  - » LIGO Livingston is exposed to heavy rain and hurricanes (but never earthquakes; we are on on a river delta, far from faults.
  - » LIGO Hanford sometimes experiences scrub fires and potentially issues related to Hanford's other activities.
  - » Lesson learned: **fit in with what the community does**. For example, when New Orleans is likely to evacuate, normal commerce and transportation is impossible in the Livingston area, so we close our gate valves and evacuate the site. This must be done days before a hurricane landfall.
- Fire & injury:
  - » Again, it is good to engage the community: at Livingston, we let the local volunteer fire fighters practice and then do their certification test using our hydrants, ponds and long access road. We are in a difficult to find location, but the fire trucks know the way!
- Question: how about at your sites?

# Long-term planning

- Among our challenges is to track and if possible react to long-term forces that would limit the facility's usefulness over the long term.
- Growth in Livingston Parish:
  - » We worried about whether ground vibration was increasing at the site over a several year time scale. After carefully examining our data, we concluded that it was **not increasing.**
  - » we worried that a high-vibration commercial site would appear nearby, displacing the forestry and low-density rural residential uses. We are working with the Parish government and economic development organization to push for development plans that respect our need for quiet.
  - » we are searching for ways to arrange for a bit more land immediately surrounding our site corner and end stations to hedge against the future during the next boom.
- Mineral Extraction:
  - » LLO is built on land acquired by Louisiana State University in the early '90s, and leased for 50 years to the NSF. The land is in the shape of LIGO's "L," surrounded completely by pine forrest.
  - » Currently, a private company is exploring for gas & oil under LIGO's part of the Parish. We established a close communications channel between their and our technical staffs, avoiding involving lawyers.